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Super Energy Efficient Housing and Solar Orientation

A RESEARCH REPORT

Super Energy Efficient Housing and Solar Orientation

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A Background Study of the Costs and Energy Benefits of the Orientation of New S.E.E. Housing for Solar Gains in Subdivisions

Sponsored by the
Energy Conservation and Oil Substitution Branch
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Prepared by
ABRICO ENERGY MANAGEMENT SERVICES LTD.
and
ENERPLAN CONSULTANTS LTD.

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ABSTRACT/RESUME

This study concludes that it appears generally feasible to design new subdivisions to give solar access to a majority of lots with little or no extra cost for land or for services. This conclusion is not true for odd-shaped parcels of land with poor orientation or with other militating constraints.

Also, there is some advantage to arranging SEE housing to obtain maximum solar gain in solar subdivisions; but with cost factors to consider, this advantage is not great enough to justify any but the simplest arrangements, such as distribution of glazing to obtain maximum solar gain.

There is some justification for placing glazing to maximize solar contribution in homes built to standards inferior to those of SEE houses. However, the usable solar gain -- while higher than in a SEE house -- becomes a very small fraction of the total heat load.

Apart from considerations of energy conservation, solar access for a majority of homes in a subdivision has considerable market value, since sun-space, greenhouses, clerestory windows and skylights are demonstrably effective as selling features.

* * *

D'après les conclusions de la présente étude, il semble qu'il est généralement possible de répartir de nouveaux lots de façon à ce que la plupart soient bien exposés au soleil sans coût additionnel, ou presque, pour la terre ou les services. Ceci n'est pas valable dans le cas de parcelle de forme irrégulière qui captent mal le rayonnement solaire ou qui, pour d'autres raisons, ne peuvent être divisées de cette façon.

On trouve aussi quelque avantage à disposer des maisons à haut rendement énergétique de façon à tirer le plus grand profit de l'ensoleillement toutefois, si l'on tient compte des coûts, cet avantage ne suffit qu'à justifier l'emploi des moyens les plus simples, notamment l'utilisation de vitrage à des fins de captage solaire maximum.

On peut justifier, jusqu'à un certain point, l'installation de vitrage pour maximiser l'utilisation de l'énergie solaire dans les maisons construites selon des normes inférieures à celles des maisons à haut rendement énergétique. Toutefois, bien qu'il y ait plus de chaleur utilisable résultant du captage solaire que dans le cas des maisons à haut rendement énergétique, celle-ci ne représente qu'une fraction minime de la charge thermique totale.

Les économies d'énergie mises à part, la plupart des maisons d'un lot ont une valeur marchande considérable si elles peuvent capter le rayonnement solaire, puisque les acheteurs recherchent manifestement des maisons dotées de solarium, de serres, de lanterneaux et de lucarnes faîtières.

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1.0 INTRODUCTION:

Phase I. of this Study, "A Critical Review of the Literature", was completed by ABRICO Energy Management Services Ltd. in April 1982 under E.M.R. Purchase Order No. 1511983.

Phase II. of the Study, "An Assessment Based on Current Information", has the following objectives:

1. To provide an assessment of the costs of additional land and the benefits resulting from planning and development to give solar orientation to subdivision lots.

2. To provide an assessment of the design and construction costs to equip a standard house with the ability to maximize the benefit from solar radiation.

3. To provide an assessment of the useful solar contribution to:

   a) a house built to "current standards",
   c) a house built to S. E. E. H. standards.
   b) a house built to intermediate standards.

General Approach:

To be useful to both developers and builders in the R-2000 Programme,* this report uses a simple format based upon clear illustrations and concise text.

The report takes account of those considerations which are basic to planning and development of subdivisions and to the marketability and sales of the houses produced.

The report is quantitative and unequivocal within the limits of the information available. It also identifies areas where relevant information is inadequate or inaccurate and where additional work may be done.

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* A federal government initiative to promote the adoption of super energy-efficient construction techniques for new homes in the residential building sector.

2.0 SOLAR SUBDIVISION DESIGN:

A "solar subdivision" is a subdivision with streets and building lots deliberately arranged so that one side of the lots and buildings on them can receive a maximum of sunlight during the winter (heating) season.

Two objectives are needed for solar subdivision design beyond those which are already established for residential land development (such as environmental protection, provision of public open space, traffic efficiency and safety, etc.)

The two solar objectives are:

1) solar orientation

A major wall of each building must face south. This is achieved primarily by orienting the building lots north-south. The front or rear elevation can then be exposed to the south, depending on which side of the street the building is sited.

2) solar access

The glazed portions of south-facing walls must have direct access to the sun throughout the heating season. This is achieved through control of siting, building height and set-back with a view to protection against shadowing from adjacent buildings, accessory buildings, garages, fences, etc.

2.1 Orientation and Available Solar Energy:

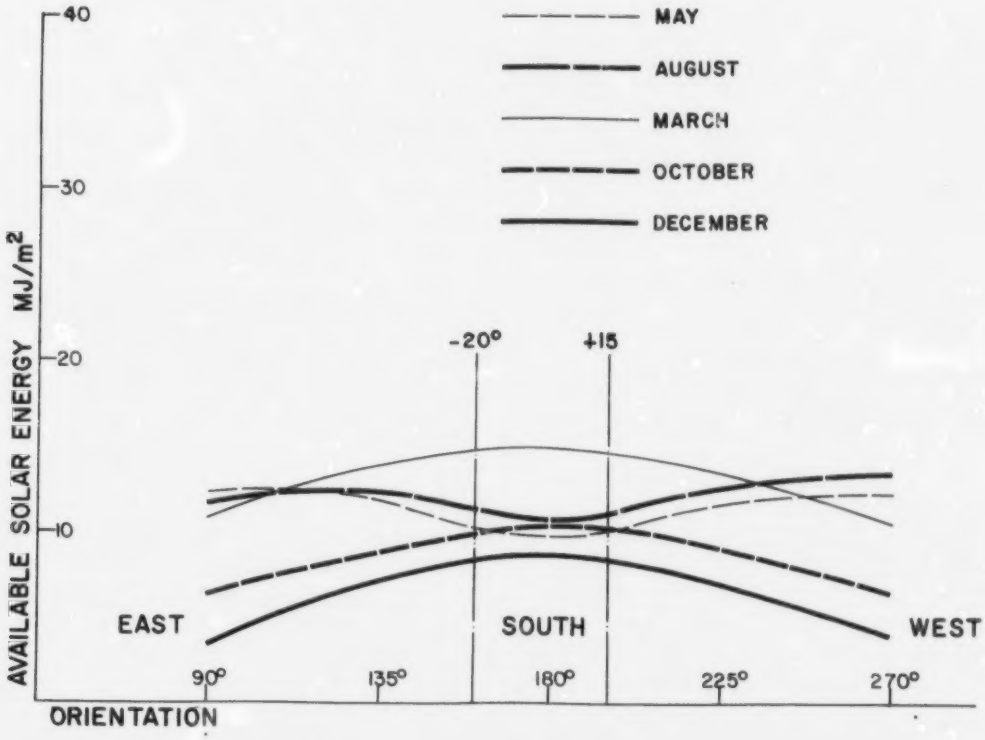


Fig. 1. Mean Daily Global Solar Radiation on a Vertical Surface. 10 year composite data from Atmospheric and Environmental Service, Canadian Climate Centre. (Data for Muskoka, Ont.)

Fig. 1. above illustrates the relationship between orientation and the amount of solar energy received by a vertical surface.

Orientations ranging from 160 degrees (20 deg. east of south) to 195 degrees (15 deg. west of south) are considered optimum. Within this range solar energy gain to the south building elevation is maximized during the winter, but kept relatively low during summer, when overheating can be the result of direct exposure to the sun. The latter is particularly true with a west orientation, since the afternoon summer sun is most intense.

2.2 The Solar Grid:

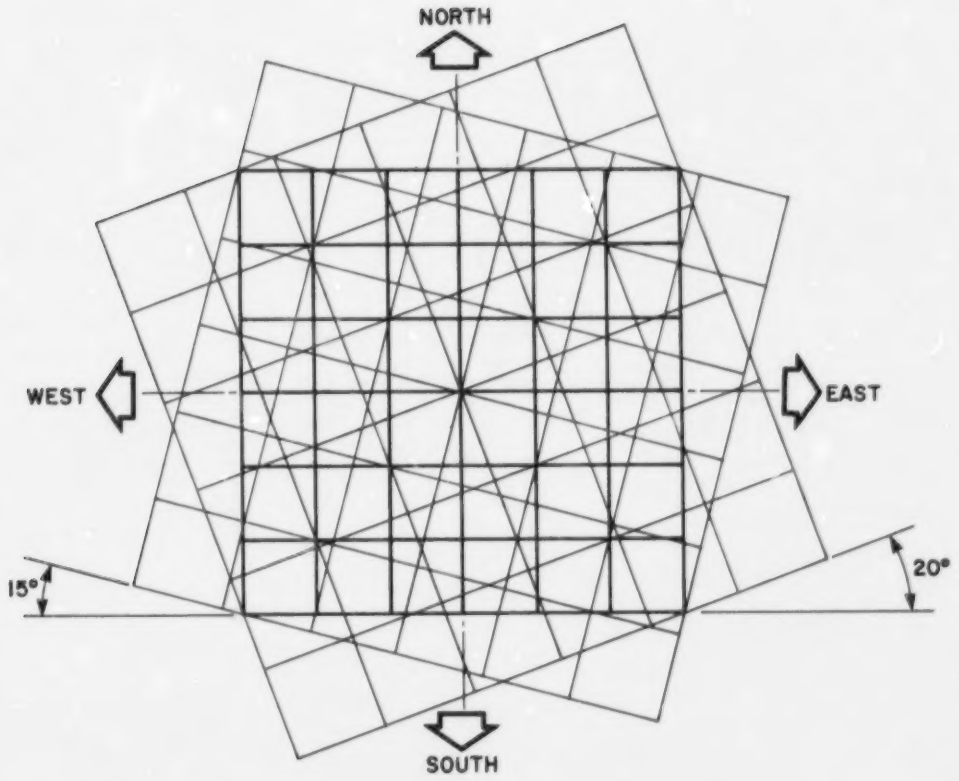


Fig. 2. Illustration of Solar Grids Oriented 20 degrees east of south and 15 degrees west of south. The heavy base grid has true south orientation.

The basic concept underlying subdivision design for solar orientation is the superimposition of a "solar grid" on the site plan. The street pattern ideally follows a general grid format with major streets aligned east-west, thereby enabling north-south orientation of building lots. In practice, a variety of design techniques and approaches can be applied to achieve the solar grid pattern

As indicated in Fig. 2., orientation of the solar grid is flexible within the range of orientations desirable for maximum solar gain.

2.3 Application of Solar Grid to Subdivision Design:

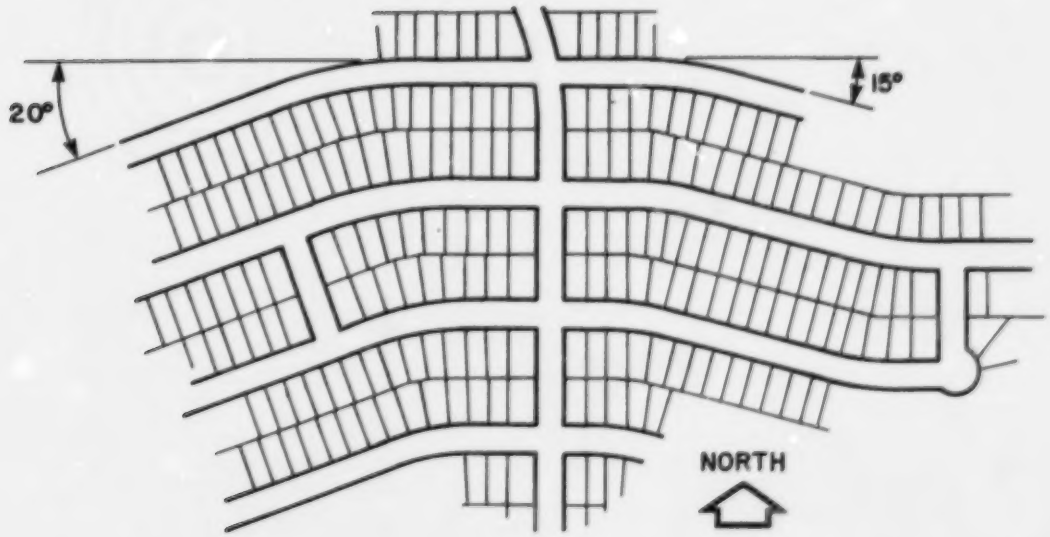


Fig. 3. An illustration of the flexibility possible in the layout of a subdivision conforming to solar design requirements.

Fig. 3. represents a hypothetical plan of subdivision with streets and lots oriented according to the solar grid.

The range of orientations inherent in the solar grid permits a degree of flexibility in subdivision layout for adapting to topography, the size and shape of the site, access constraints and it also allows for the desire for visually interesting and safe, functional street patterns.

2.4 Solar Access: The Impact of Latitude and Topography:

Fundamental to solar access is the distance separation between buildings. There must be sufficient distance between buildings to insure that those to the north are not shaded by those to the south.

The key variables for determining the required distance separation are latitude and topography. Fig. 4a. and 4b. illustrate this using two examples: Toronto and Edmonton.

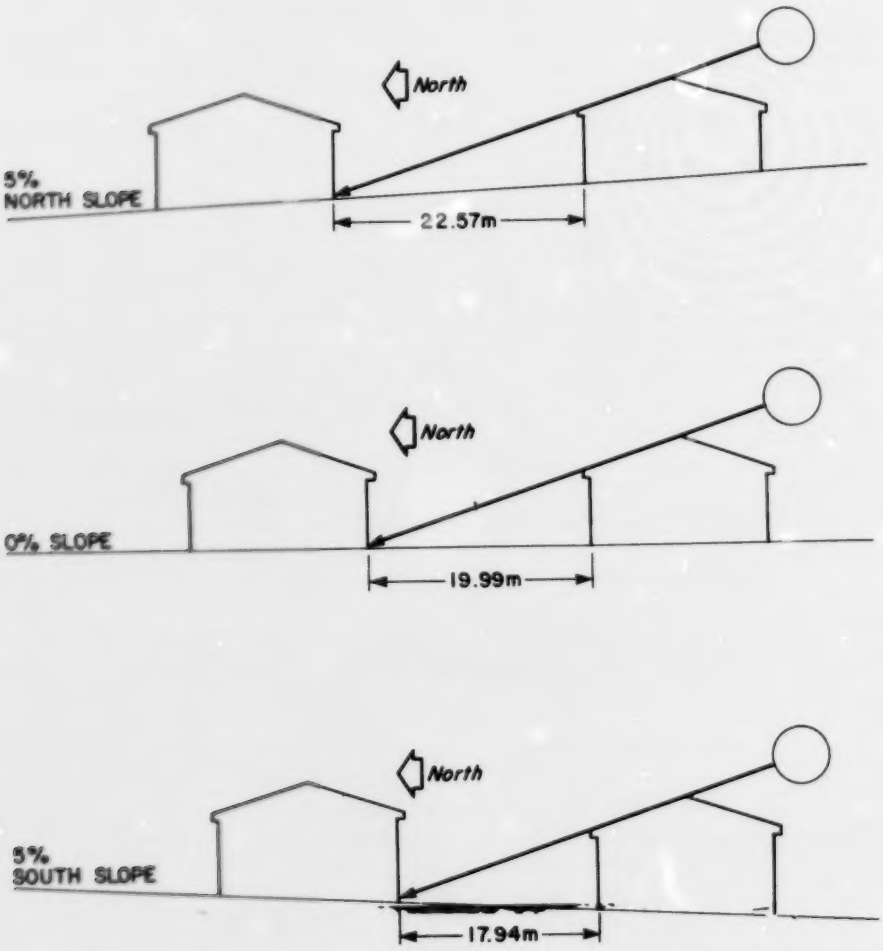


Fig. 4a. Implications of Latitude and Slope for Solar Access Toronto 43.5 deg. N. 18.5 deg. solar height restriction plane.

In Toronto, where the sun angle is 18 degrees and most new residential development is one-and-a-half or two stories, sufficient distance separation can be achieved on standard lots, even when there is a 5% north slope.

In Edmonton, where the sun angle is 11 degrees and most residential development is one story, sufficient distance separation can be achieved on standard lots, except when there is a north slope.

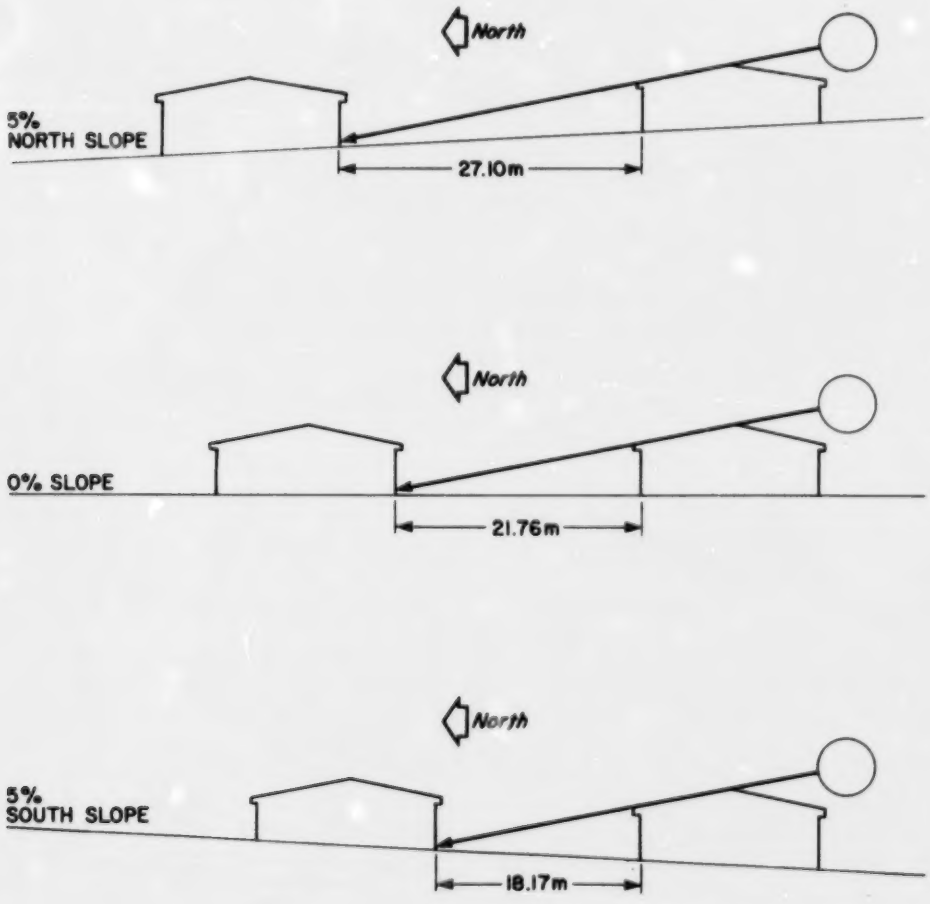


Fig. 4b. Implications of Latitude and Slope for Solar Access
Edmonton 53.5 deg. N 11 deg. Solar Height Restriction Plane.

3.0 COSTS AND BENEFITS OF SOLAR SUBDIVISION DESIGN:

The purpose of Section 3.0 is to assess the costs and benefits of land development associated with incorporating solar orientation and access objectives into subdivision design.

The assessment is based on two case studies. The Paramount Subdivision (case study A) and the Alliance Subdivision (case study B) are both located in Brampton, Ontario, and represent pioneering efforts in solar subdivision design. In both cases a "conventional plan" and subsequently a "solar plan" were prepared for the same sites. Also in both cases the solar plan is approved and under construction. These case studies provide actual costs of solar planning approaches and are therefore superior to hypothetical studies. However, the solar and conventional plans are not strictly comparable, as discussed below.

3.1 Potential Cost and Benefit Implications:

To date, Canadian experience in solar subdivision design is limited; and virtually no quantifiable information exists concerning the the implications of solar design techniques for the costs and benefits of land development. However, a number of areas can be identified where costs and benefits associated with solar design techniques may exist.

1) roads and underground services
Planning for solar orientation is based on the solar grid pattern of streets. This differs substantially from the more conventional, curvilinear pattern used in most recent residential subdivisions. Since the cost of underground services (water, sewers, electricity and natural gas) as well as the costs of road and walkway construction vary with road pattern and total road length, design for solar orientation may have an important effect on development costs.

2) site grading and landscaping
Imposition of a grid street pattern may incur additional costs for "cut and fill" in situations where topography is inappropriate. Also, there may be costs associated with energy conscious landscaping, including location of vegetation for shading and wind control.

3) yield
The amount of salable frontage yielded from a subdivision may be affected by using a grid pattern instead of a more conventional pattern. Yield may also be affected if solar access requires that lot sizes be increased to insure sufficient distance separation between buildings.

4) development approvals procedures
The consideration of solar objectives in plans of subdivision may require additional processing time and effort on the part of various municipal and provincial approval agencies. This would have cost implications for the agencies involved as well as for the developer who must carry the costs of holding the land in a highly competitive market.

5) marketability
The incorporation of solar lots into subdivisions has potential implications for the salability and market price of lots to builders; and ultimately of homes to consumers. This affects both the rate and amount of revenue return to the developer.

The following case studies provide quantifiable data on costs and benefits of solar subdivision design. The results can be considered indicative rather than definitive, since the studies are limited and the field is very new; however, these actual cases permit the analysis to be made on real land developments as opposed to hypothetical studies.

3.2 Case Study A: The Paramount Subdivision:

The Paramount Subdivision is located on a 29.6 ha (73.14 acre) site in Brampton, Ontario. A conventional plan for the site (Fig 5a.) was prepared and submitted for approvals on 1 October 1979. In accordance with energy policies and regulations instituted by the Municipality at that time, the plan was redesigned for solar orientation and access (Fig. 5b.). The solar plan was Draft Approved on 14 August 1980. The site has since been serviced and sold to a builder, Great Gulf Homes Ltd. Construction is currently in progress and includes conventional detached homes and, notably, a cluster of energy efficient houses built under the auspices of the federal-provincial "Energy Efficient Subdivisions" program.

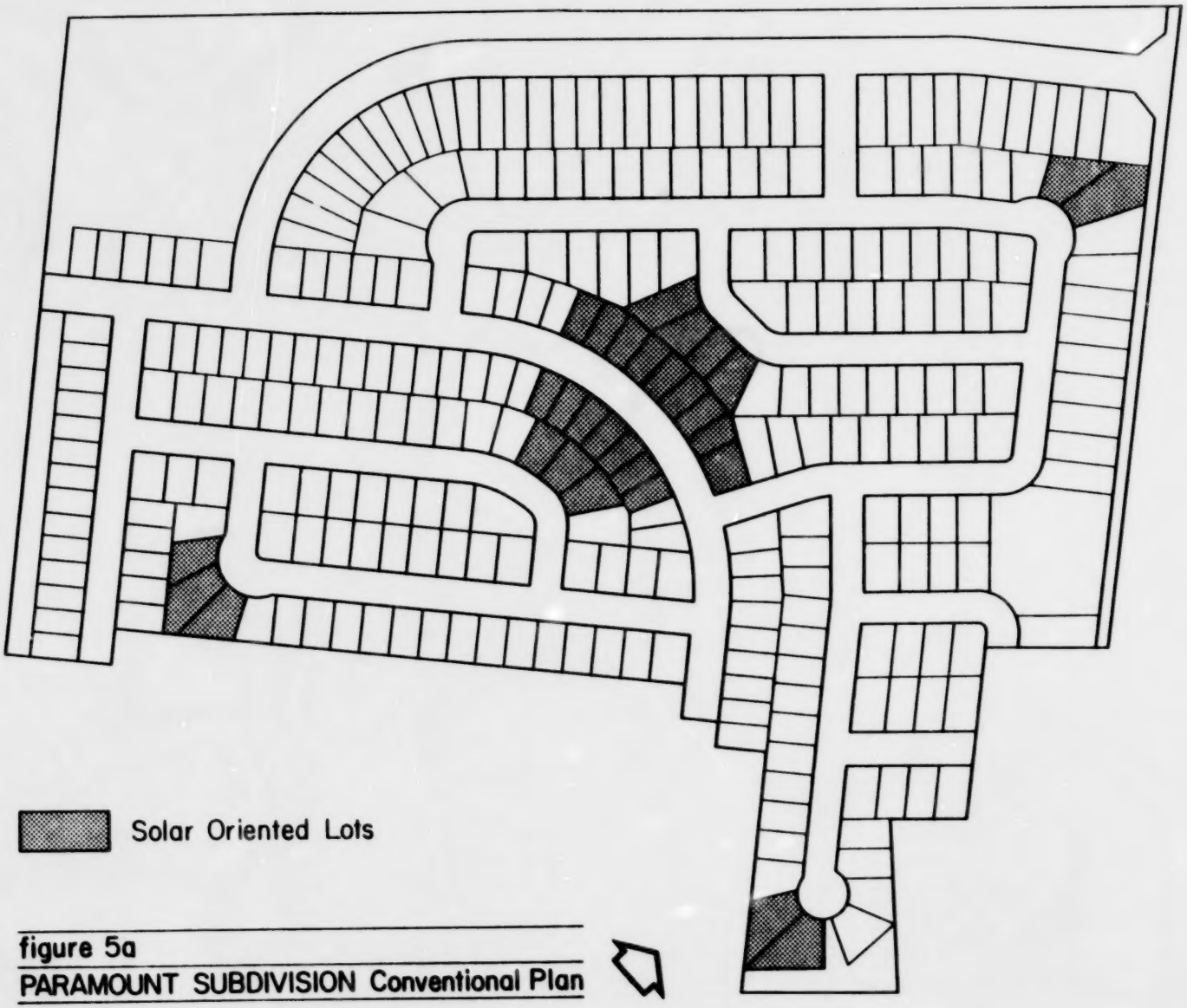


figure 5a
PARAMOUNT SUBDIVISION Conventional Plan

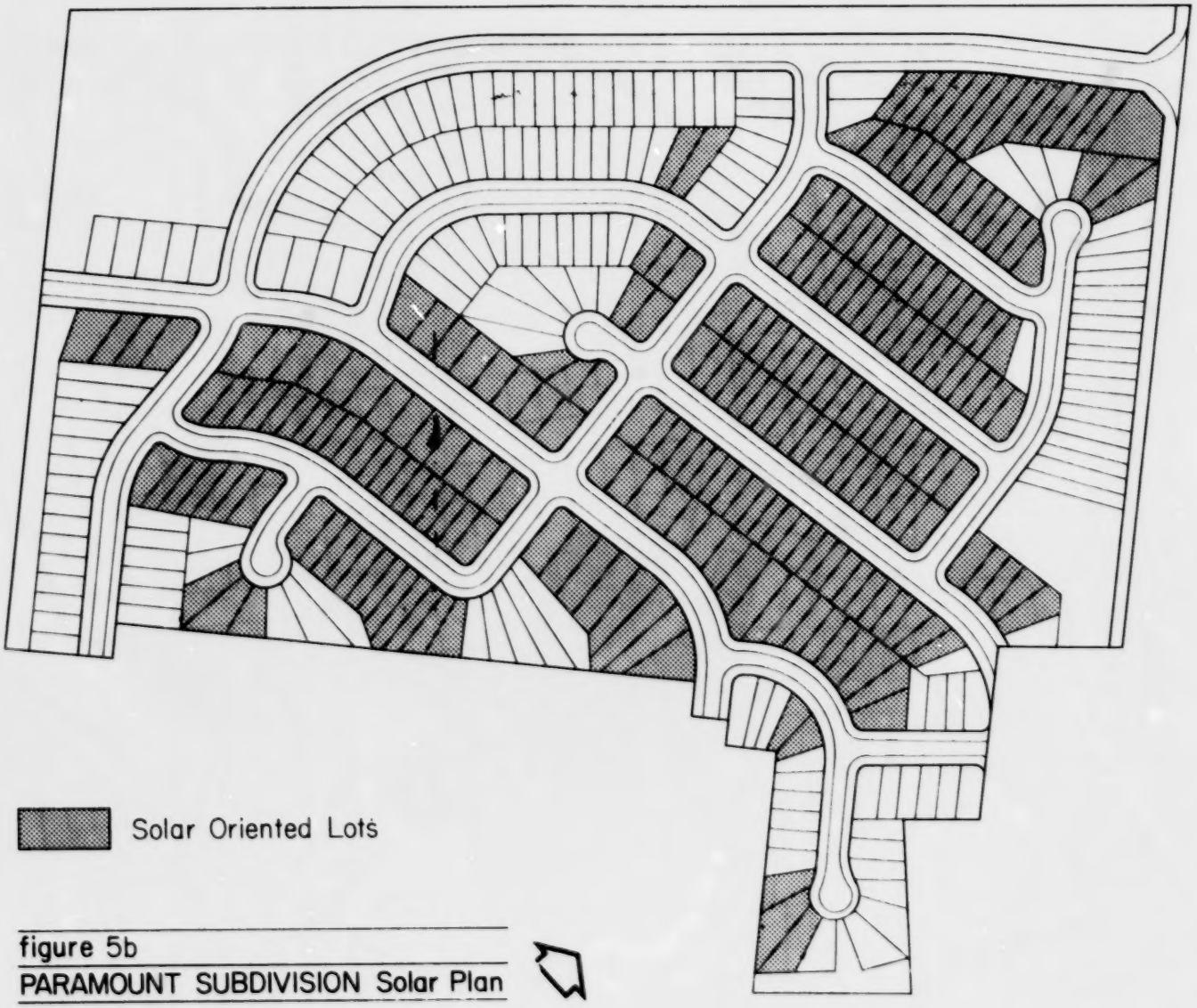


figure 5b
PARAMOUNT SUBDIVISION Solar Plan

3.2.1 Roads and Underground Services:

A comparison of the coventional and solar plans shows that there are substantial differences in street patterns and lot arrangements. The Paramount site presented serious constraints for solar planning. The site, defined notably by existing concession roads and an irregular property boundary along the southern edge, is oriented approximately 45 degrees to the south-east, away from the north-south axis. Consequently, the imposition of a solar grid leaves awkward corner pieces which are accessible only by cul-de-sacs and are difficult to design for orientation and access.

Table 1a., which summarises data on the conventional and solar plans, reveals that total road length was reduced from 3610 metres to 3390 metres in redesigning the subdivision. Since this is a flat site presenting no topographical constraints, the costs of roads and underground services are generally proportional to road length, as reflected by the cost figures of Table 1b. The costs of roads and underground servicing shown in Table 1b. for the solar subdivision are the actual costs determined from financial records. Those for the conventional subdivision are estimates proportional to road length.

Similarly, the capital costs of electrical utility servicing would have been higher for the conventional plan as a result of the increased number of "hook-ups" (increased number of units). The natural gas utility infrastructure costs would have been slightly lower for the conventional plan. It is estimated that the costs of lot grading and landscaping would be the same for both plans. Experts involved in the Paramount development could see no reason why one plan would incur more grading and landscaping expense than the other on this flat site.

Overall, based on the comparative analysis of the two plans and on consultation with the various officials involved in the site development, the conventional plan would be slightly more expensive to service than the solar plan.

3.2.2 Net Salable Frontage:

Table 1a. indicates that Net Salable Frontage (NSF) was reduced from 5182 metres in the conventional to 4475 metres in the solar plan. The reduction was in large measure due to increased lot depth in the solar plan. This modification was tied to changes made in the mix of housing types to meet changing market demand. Consequently, one cannot say that solar design objectives were the only factors in affecting road length, NSF yield, lot or unit yield.

Table 1a. The Paramount Subdivision
Physical Comparison Between Conventional and Solar Plans

	Conventional	Solar
Total Road Length	3610 m	3390 m
Net Salable Frontage	5182	4475
Net Salable Solar Frontage	458	2919
Net Residential Area	17.7 ha	18.3 ha

Table 1b. The Paramount Subdivision
Servicing Costs of the Conventional and Solar Plans

	Conventional	Solar
Roads and Underground Services (sewer, water)*1	$ 2,392,400	$ 2,246,500
Electrical Utility *2	639,484	546,000
Natural Gas Utility *3	-	-
Lot Grading *4	108,400	108,400
Landscaping *5	235,000	235,000

NOTES: *1) solar plan costs are actual; conventional plan costs are an estimate based on proportionality to road length.

*2) solar plan costs are actual; conventional plan costs are an estimate based on proportionality to road length.

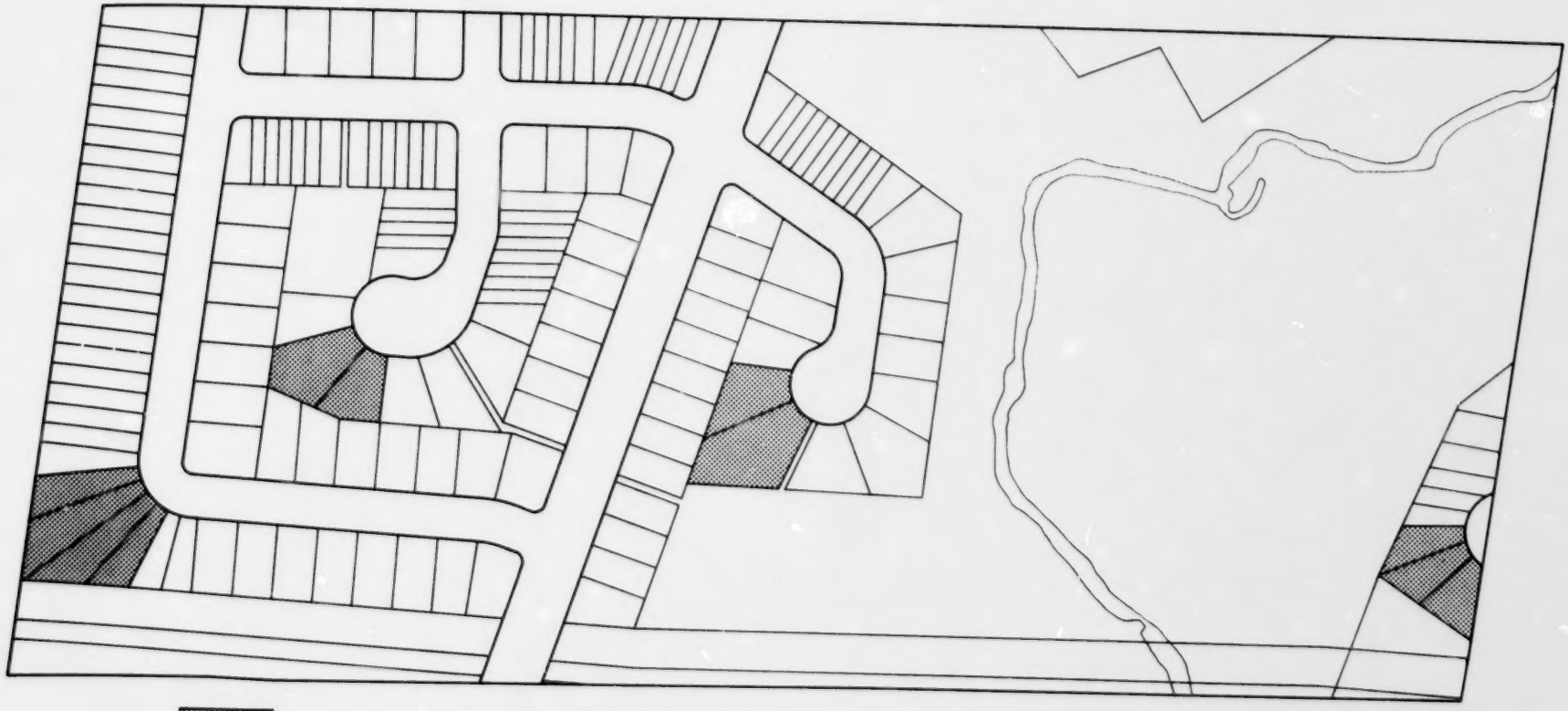
*3) capital costs for the natural gas infrastructure were not available; however, Consumers' Gas officials estimate that capital costs for the solar plan would have been 2.6 % more than for the conventional plan (increased grid main requirements).

*4) and *5) lot grading and landscaping costs for the solar plan are actual; conventional plan costs are estimated to be equal due to flat topography.

3.3 Case Study B: The Alliance Subdivision:

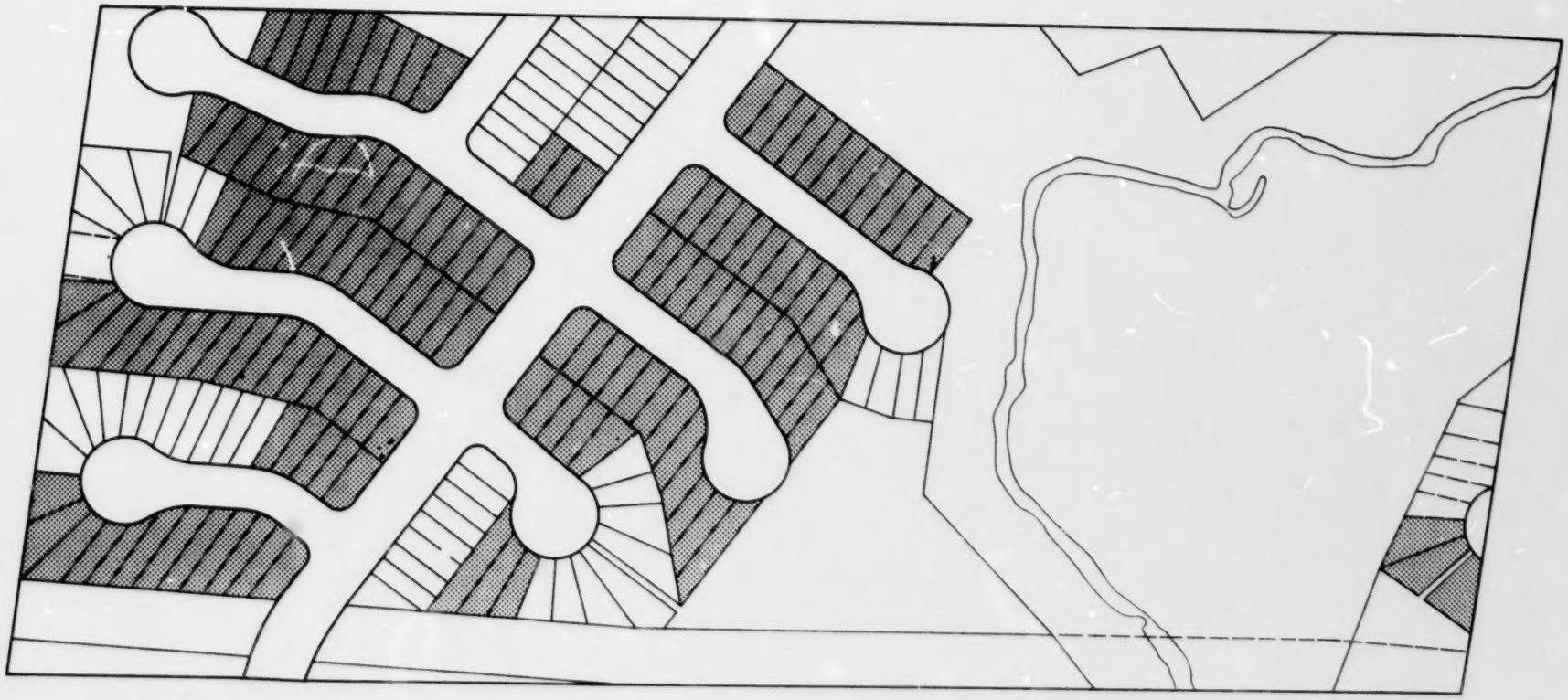
The Alliance Subdivision is on a 20.3 ha (50 acre) site and is also in the City of Brampton. The conventional plan was submitted for approval in January 1979. As in the Paramount case, this plan was completely redesigned to meet municipal objectives of solar orientation and access. The resulting solar plan was Draft Approved in April 1979. Roads and services are currently under construction. The site has been sold to Lakeview Properties Ltd., a builder now in the process of pre-selling small, single detached homes. The houses are of conventional design, with minor modifications to take advantage of passive solar energy (e.g., modified overhangs, careful distribution of glazing, etc.)

SEE NEXT PAGE



Solar Oriented Lots

figure 6a
ALLIANCE SUBDIVISION Conventional Plan



Solar Oriented Lots

figure 6b
ALLIANCE SUBDIVISION Solar Plan

A comparison of the Solar Plan (Fig. 6b.) with the Conventional Plan (Fig. 6a.) shows that a very distinct design solution was applied to achieve solar orientation. A pattern of east-west streets crossing an arterial road and ending in cul-de-sacs was used to provide orientation given some severe site constraints. In particular, a provincial highway to the west and a ravine to the east bounded a relatively small, awkward site with limited access potential and less than ideal orientation. The use of multiple cul-de-sacs has had important effects. Although east-west street orientation is made possible on a difficult site, "fanning" lots at the ends of cul-de-sacs reduces lot efficiency and necessitates the incorporation of several lots with poor orientation.

3.3.1 Roads and Underground Services:

Road length analysis shows that the solar plan has slightly more road length than the conventional plan (Table 2a.). Since the developable portion of this site is flat, road length provides a good indicator of road and underground servicing costs. In this particular aspect, cost for the conventional plan is slightly higher than for the solar plan (Table 2b.). The Table also shows that the costs for electrical and natural gas utilities would vary only slightly betwen the two plans. Lot grading and landscaping costs would be the same.

Overall, due to similarity of road length and unit yield and the generally flat topography, servicing costs for the two plans would vary only marginally.

3.3.2 Net Salable Frontage:

Analysis of yields from the conventional and solar plans provides a similar overall result: a minimal variation between the plans. The difference between Net Salable Frontage for the conventional plan of 1854 metres (6083 ft) and the solar plan of 1849 metres (6065 ft) is negligible. Lot yield was reduced slightly in the solar plan, but it is difficult to attribute this to solar orientation, given the major changes in unit mix and lot sizes. Once again, lot and unit yield differences between the two plans were the direct consequences of changes in market demand.

Table 2a. : The Alliance Subdivision
Physical Comparison Between Conventional and Solar Plans

	Conventional	Solar
Total Road Length	1312.2 m	1290 m
Salable Frontage	1854 m	1848.6 m
Salable Solar Frontage	157 m	1385.3 m
Net Residential Area	7.41 ha	7.20 ha

Table 2b. : The Alliance Subdivision
Servicing Costs of the Conventional and Solar Plans

	Conventional est.	Solar actual
Roads and Underground Services (sewer, water) *1	$ 1,202,840	$ 1,241,767
Electrical Utility *2	312,570	292,940
Natural Gas Utility *3	-	-
Lot Grading *4	$ 25,640	25,640
Landscaping	N/A	N/A

NOTES: *1) solar plan costs are actual; conventional plan costs are an estimate based on proportionality to road length.

*2) costs for both plans are estimates based on a standard factor applied by Brampton Hydro, $ 1510.00 per dwelling unit.

*3) capital costs for the natural gas infrastructure are not available; however, Consumers' Gas officials estimate that the capital cost for the solar plan would have been 9 % more that for the conventional plan.

*4) Lot grading costs for the solar plan are actual; costs for the conventional plan would have been approximately equal because of the flat topography.

3.4 Discussion

Case studies of actual solar development projects, such as the two studied in this paper, are useful subjects for a realistic analysis. They demonstrate, however, that it is difficult to isolate the effects of solar objectives on development costs and revenues.

Three important points must be made regarding the comparability of the conventional and solar plans evaluated in this study:

- the lot and unit yields for each developer (Paramount and Alliance) were different for their respective conventional and solar plans, due in part to market demand changes and hence not simply the result of a change in design parameters.

- the switch from conventional subdivision layout and lot design to a solar plan has a direct impact on lot yield in one important way, by altering the amount of Net Salable Frontage (NSF). The less the NSF, the lower the lot yield; the more NSF, the higher the lot yield (when lot dimensions -width and depth- do not change). In the Paramount case, an increase in the depth of lots (in response to market demand developing after the conventional plan had been prepared) had the effect of reducing NSF on the site. This would have occurred whether the plan had been conventional or solar.

- the developer's gross revenue is largely derived from -or is a function of- the amount of NSF on a given plan.

In the Paramount case, for example, both servicing costs and frontage yield were reduced by redesigning to meet solar objectives; but any attempt to attribute these reductions specifically to solar orientation and access has had to be qualified in view of the other changes (alterations in lot depth and unit mix) which were made during the redesign of the subdivision. In the Alliance case, on the other hand, even though there was a change in housing mix and therefore in lot dimensions, there was very little difference in Net Salable Frontage and overall costs between the conventional and solar plans.

To some extent, each development site is unique, presenting its own set of design constraints. Despite these qualifications, some general conclusions can be drawn, as follows:

1. A reasonable degree of solar orientation can generally be achieved with no real impact on land use or servicing efficiency. What is "reasonable" depends largely upon the overall orientation and shape of the site. In an oddly shaped, poorly oriented site, a reasonable objective may be 50-60% of lots with a good solar orientation. For a rectangular, well-oriented site, as high as 90% may be reasonable. Solar orientation is like any other planning objective. If carried to extremes, it will incur extra costs; otherwise, it can be integrated successfully into the design process.

2. Cost effective solar subdivision design will depend to a large degree upon the particular skills and resources of the designer working with a particular site. Information, education and the continued development of solar design techniques are essential.

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4. COST AND BENEFITS OF CONSTRUCTION FOR PASSIVE SOLAR GAIN:

Three qualities of construction are compared in this section:

1) Super Energy Efficient Housing (S.E.E.H.)

2) Housing meeting Current Building Codes

3) Housing of a quality intermediate between the two.

Table 3. (next page) lists the thermal resistance features of each type of construction.

A standard house type was chosen for comparison of the three different qualities of construction at two locations, Toronto and Edmonton. This was a 8m X 12m bungalow with full basement with concrete walls and footing. The glazed area amounted to 13.5 % of the living floor space. South windows were furnished with a standard overhang (See Appendix I for details).

To calculate the thermal performance of houses constructed to the different standards of insulation, computations were made using a version of the HOTCAN! program developed by Lux et al(4,5) containing routines for determining utilizable net solar gains derived from the methods of Barakat and Sander (1,2) and methods for basement heat loss calcuations developed by Mitalas (6,7).

Barakat and Sander (Table I, Ref.2) have determined utilizable solar gains for four types of construction: Light, or standard frame construction; Medium, with added interior gyproc; Heavy, with added interior brick and gyproc; and Very Heavy, commercial office building with concrete floors. In this comparison, all houses were assumed to be standard construction without extra mass to absorb solar heat, it being considered unlikely that any but custom designed houses would have the features of heavier construction. For this reason also, trombe walls and other special passive features have been excluded from the comparison. As required by the above methods of calculation, it was assumed that all heat loss components could be offset by solar gains whenever these were available. It was further assumed that there would be no night set-back of thermostats, no use of thermal blinds or shutters and no interference with solar access.

Tables 3. and 4. summarise the results of calculations.

Table 3 : Characteristic Thermal Resistance Values (RSI)* for construction types considered in this section.

	Type		
	S.E.E.H.**	Intermediate	Current***
Ceiling	10.6	6.1	4.9
Walls	8.4	3.5	2.2
Windows	0.35	0.35	0.35
Doors	1.7	0.7	0.35
Basement Walls			
above grade	5.5	2.5	1.41
below grade	3.5	1.5	0.47
Basement Floor	1.8	0.0	0.0
Infiltration/ Ventilation (air-changes/hour)	0.1	0.3	0.5

* RSI X 5.7 = conventional R units

** These values are those achieved in Saskatchewan (H. W. Orr, Building Practice Note No. 30, April, 1982). The Saskatchewan models will easily meet the Toronto requirements of 35 kWh/sq.m., but probably represent an unnecessary degree of insulation for Toronto. However, this degree of insulation would be required in Edmonton.

*** These values correspond to the "1980 minimum standards" used as a reference design by Dumont and Orr (Building Research Note No. 176, Sept. 1981). They are almost identical with the values of the current Ontario Building Code.

Table 4. Summary of Heating Loads of Three Types of Houses
Heating season: October to May inclusive.
Results are from computations by HOTCAN!

	Toronto	Edmonton
S.E.E.H. Standard*	5220 kWh/y	9580 kWh/y
S.E.E.H. Solar**	4500	8440
S.E.E.H (Solar vs Standard)		
Seasonal Energy Saving =	720 kWh	1140 kWh
=	2.59 GJ	4.10 GJ
@ $10.00/GJ Savings =	$ 25.90	$ 41.00
Standard Heating Bill =	$ 188.00	$ 345.00
% Saving =	13.8 %	11.9 %
Intermediate Standard*	11,750 kWh/y	19,510 kWh/y
Intermediate Solar**	10,860	18,080
Intermediate (Solar vs Standard)		
Seasonal Energy Saving =	890 kWh	1430 kWh
=	3.20 GJ	5.14 GJ
@ $10.00/GJ Savings =	$ 32.00	$ 51.40
Standard Heating Bill =	$ 423.00	$ 702.00
% Saving =	7.5 %	7.3 %
Current Standard*	20,670 kWh/y	32,980 kWh/y

NOTE: Building to Current Code not tested in a solar version.

* Standard design has an equal distribution of glazing on each of the four faces of the building.

** Solar means maximising glazed areas on the south face of the building and reducing glazing on other faces, particularly the north face, by an equivalent amount. No other measures were taken.

4.1 Discussion:

The comparisons made here are mainly between a house constructed to S.E.E. standards and one constructed to "intermediate" standards, since it would be unlikely that a house constructed to current standards would be designed as a "solar" house.

Clearly, incremental construction costs must be kept to a minimum, since the absolute amount of savings due to solar gains is not large. It is instructive to compare the utilizable solar gains of the S.E.E. and "intermediate" houses.

The seasonal energy saving of the intermediate house in Toronto is 3.20 GJ; whereas that of the tighter and better insulated S.E.E. house is 2.59 GJ. The explanation lies in the term "utilizable". The allowable temperature swing in both houses was 2.75 deg.C. To maintain house temperature within this range, the S.E.E. house had actually to reject some solar heat (open windows, pull down blinds, etc. This eventuality is taken care of in the HOTCAN! computation). The thermal losses in the intermediate house were much higher and most, if not all of the solar gain could be utilized without exceeding the allowable temperature swing.

4.1.1 Incremental Construction Costs:

If heavier construction had been used in the S.E.E. house (e.g. double thickness of gypsum wallboard) the excess heat could have been "utilized" in heating up this extra mass. However, the amount thus saved is not likely to be much greater than 0.6 GJ (i.e. about $ 6.00 per season). The incremental cost of the extra mass in the walls and ceiling of the S.E.E. house in Toronto would come to approximately $ 5.00/sq.m. (8.). This would be a total of

$$(\$5.00 \times 81.8) + (\$5.00 \times 96) = \$\ 889.$$

There is thus little justification in doubling the amount of gypsum wall board.

Similarly, it is difficult to justify other special modifications to S.E.E. housing for additional solar gain. Note, however, that the relocation of glazing costs nothing and produces a useful saving of energy amounting to 13.8% of the annual heating load.

For this reason we are justified in making only the simplest comparison among the two standards of construction, keeping costs to a minimum by merely relocating glazing to take advantage of solar access.

The incremental costs of upgrading a bungalow of the type studied here from the reference building (i.e., current Ontario Building Code) to S.E.E quality construction varies considerably from one site to another. Current estimates by the HUDAC national office put the spread of costs as $1500 to $2500. Earlier estimates by Dumont and Orr (B.R.N. No. 176, Ref.9.) for upgrading a conventional house to S.E.E.H. standards in Saskatoon are $3500 to $3700 (1981). By the end of 1982 the number of S.E.E. quality houses constructed in Saskatchewan was approaching 200; and there are several builders prepared to offer S.E.E. quality construction of homes comparable to the bungalow in this study at incremental costs in the range of $1500 to $2000.

On a national basis, incremental costs are considerably higher owing to lack of experience among builders. In the recent S.E.E.H. demonstration program administered by HUDAC for the federal government and the provinces an amount of $6500 has been allocated for each house built to acceptable S.E.E. standards. Of this $2000 is identified as a "design fee" and $3000 as an incentive to the builder.

A realistic incremental cost to the buyer (including builder's profit) may be taken as $2500 to $3500, depending upon the region in which the house is built.

Since the seasonal saving due to utilizable solar gain is no more than $25 to $35, S.E.E. type construction is certainly not justified as a means of maximizing solar gain; but clearly <u>is</u> justified as a means of reducing heating cost.

4.1.2 Marketability Considerations:

The Phase I Study referred to in the Introduction has shown that -quite apart from energy considerations- homes designed to maximize solar access have "curb appeal". Experience in California and Colorado (See Phase I Study) has demonstrated conclusively that the <u>marketability</u> of housing was greatly enhanced by solar lighting of clerestory windows, south facing glazed areas and solar greenhouses even when these features <u>detracted</u> from the energy efficiency of the housing envelope. Thus there is a practical and financial argument for solar orientation quite apart from energy considerations. While this should probably not be an element of government policy, it is certain to be a major consideration on the part of builders and developers.

5.0 SUMMARY AND CONCLUSIONS:

The first objective of this study was "to provide an assessment of the costs of additional land and the benefits resulting from planning and development to give solar orientation to subdivision lots".

This assessment has revealed that, overall, incorporating solar objectives into the subdivision design process does not necessarily incur additional development costs. It is feasible to design new subdivisions for solar access to a reasonable number of building lots with little or no incremental cost for land or services. What is "reasonable" depends on characteristics of the development site. Fifty or sixty percent may be reasonable for odd-shaped , poorly oriented sites; while ninety percent may be reasonable for rectangular well-oriented sites. There are numerous considerations involved in subdivision planning; and solar orientation can be incorporated successfully as one of these by a qualified planning team.

The second objective was "to provide an assessment of the design and construction costs to equip a standard house with the ability to maximize the benefit from solar radiation".

As shown in Section 4., design to maximize solar benefits merely involves orientation of glazing, essentially at no incremental cost. The HOTCAN! computations show that -for a fixed allowable temperature swing- utilization of available solar energy during the heating season is actually higher in the house constructed to "intermediate standards" than it is in the S.E.E. house; since the latter must reject some solar heat in order to stay within the allowable range of temperatures. The absolute quantity of solar energy gained in both cases is small compared to the heating load and does not justify the cost of elaborate refinements to maximize the solar contribution.

The incremental cost of construction to increase thermal efficiency to the level exhibited by S.E.E. housing varies considerably from one site to the next. A reasonable range appears to be from $2500 to $3500 for "light and tight" construction. Clearly, such measures are not justified if the aim is merely to maximize solar benefits, since the dollar value of the solar gain is of the order of $25. S.E.E.H. quality construction is justified on the grounds of savings in the annual heating costs.

The third objective was "to provide an assessment of the useful solar contribution to:

a) a house built to "current standards",
b) a house built to S.E.E.H. standards,
c) a house built to intermediate standards."

Data on solar contributions are summarized in Table 4., p.24. The useful contribution to a S.E.E. house is approximately 14% of the seasonal heat load; and -in the absence of other considerations- would justify solar orientation of a S.E.E. house to obtain this benefit alone. Similarly, the solar benefits to housing of intermediate standards are appreciable, although the fractional solar contribution is much less.

No data were obtained for solar contributions to houses built to current standards, it being assumed that no attempt would be made to maximize solar gains as an energy contribution in such houses (the fractional contribution would be too small). However, the advantages of solar orientation in providing daylight and sun-space cannot be ignored, since these attributes have an extremely important effect on the marketability of new housing in subdivisions.

6.0 BIBLIOGRAPHY:

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2. S. A. Barakat and D. M. Sander "Utilization of Solar Gain Through Windows for Heating Houses", National Research Council of Canada, Building Research Note No. 184, Ottawa, March, 1982.

3. R. S. Dumont and H. W. Orr "Cost of Energy Conservation Measures for New Housing", National Research Council of Canada, Building Research Note No. 176, Ottawa, September, 1981.

4. M. E. Lux "HOTCAN Program Manual for Apple II Plus Computer", National Research Council of Canada, Prairie Regional Laboratory, Saskatoon, Sask. July, 1982.

5. R. S. Dumont, M. E. Lux and H. W. Orr "HOTCAN: A Computer Program for Estimating the Space Heating Requirement of Residences", National Research Council of Canada, DBR Computer Program No. 49, Ottawa, August, 1982.
NOTE: Validation of the program by R. S. Dumont against homes in Saskatchewan has shown the program to be accurate to 15-20%. Dumont, Private Communication, March, 1982.

6. G. P. Mitalas "Net Annual Heat Loss Factor Method for Estimating Heat Requirements of Buildings", National Research Council of Canada, Building Research Note No. 117, Ottawa, 1976.

7. G. P. Mitalas "Basement Heat Loss Studies at DBR/NRC", National Research Council of Canada, Building Research Paper No. 1045, Ottawa, 1982.

8. Construction Data Systems Ltd. and Hanscomb Consultants Inc. "1982 Yardsticks for Costing", Southam Business Publications, Don Mills, Ontario, August 1982.

9. ABRICO Energy Management Services Ltd. "Super Energy Efficient Housing: What Benefits from Orientation for Passive Solar Gain? Phase I. A Critical Review of the Literature", Energy Mines and Resources Canada, Unpublished Report, Ottawa, March 1982.
NOTE: Although not referred to directly, this review considers many of the questions raised in the present report.

7.0 APPENDICES

Appendix I: Typical HOTCAN Output

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* * * * * * * * * * * * * * * * * * * * *
*                                         *
*              PROGRAM HOTCAN!            *
*  NATIONAL RESEARCH COUNCIL OF CANADA    *
*     DIVISION OF BUILDING RESEARCH       *
*     SASKATOON, SASKATCHEWAN, 1982       *
*           RELEASE S3-820809             *
* * * * * * * * * * * * * * * * * * * * *
```

CLIENT NAME: ABRICO ENERGY MANAGEMENT
ADDRESS : LAKEFIELD

USER DATA FILE NAME: ABRIEDM,HOTCAN

DATA IS FOR EDMONTON

*** BUILDING PARAMETERS ***

ELEMENT	AREA M2	RSI VALUE M2-DEGC/W	HT LOSS W/DEGC	% SEASONAL HT LOSS
CEILING	96	10.6		
TOTAL	96	10.6	9.06	7.08
MAIN WALLS	81.8	8.4		
TOTAL	81.8	8.4	9.74	7.61
DOORS	3.6	1.8		
TOTAL	3.6	1.8	2	1.56
BASEMENT AB.GD	20	5.5		
TOTAL	20	5.5	3.64	2.84
BASEMENT 600MM	40	3.5		
TOTAL	40	3.5	9.02	5.97
BASE. TO FLOOR	24	3.5		
TOTAL	24	3.5	10.54	6.97
FLOOR PERIMETER	36	1.8		
TOTAL	36	1.8	14.29	9.45
FLOOR CENTRE	60	1.8		
TOTAL	60	1.8	9.5	6.28
SOUTH WINDOWS	10	.5		
TOTAL	10	.5	20	15.63
NORTH WINDOWS	1	.5		
TOTAL	1	.5	2	1.56
EAST WINDOWS	1	.5		
TOTAL	1	.5	2	1.56
WEST WINDOWS	1	.5		
TOTAL	1	.5	2	1.56
AIR CHANGE	.23/HR	576 M3	40.87	31.93

CLIENT NAME: ABRICO ENERGY MANAGEMENT
ADDRESS : LAKEFIELD

DESIGN HEAT LOSS AT -32.2C = 5.74 KW
TEMPERATURES (DEG C) MAIN FLOOR = 21 BASEMENT = 18
SENSIBLE HEAT GAIN FROM PEOPLE (KWH/D) = 3.2
DAILY BASE ELECTRIC CONSUMPTION (KWH/D) = 14
DAILY HOT WATER ENERGY CONSUMPTION (KWH/D) = 14
MASS LEVEL CHOSEN IS <A>
WINDOW SHADING COEFFICIENTS: SOUTH = .8 NORTH = .8
EAST = .8 WEST = .8
SOUTH OVERHANG GEOMETRY: AVERAGE WINDOW HEIGHT = 1.52 M
AVERAGE OVERHANG WIDTH = .61 M
AVERAGE HEIGHT ABOVE WINDOW = .2 M
NATURAL INFILTRATION RATE (AC/HR) = .08
FORCED VENTILATION RATE (AC/HR) = .5
HEAT RECOVERY EFFECTIVENESS ON VENTILATION AIR = 70%

*** MONTHLY SUMMARY OF ENERGY CONSUMPTION ***

MONTH	THERMAL LOAD KWH/D	MONTHLY SOLAR FRAC	AUX HEAT REQ KWH/D	TOT CONS KWH/D
JAN	82.19	.25	61.61	89.61
FEB	73.45	.34	48.64	76.64
MAR	62.22	.42	35.94	63.94
APR	38.18	.57	16.34	44.34
MAY	21.06	.73	5.65	33.65
JUN	11.02	.91	1.04	29.04
JUL	3.37	1	0	28
AUG	6.63	1	0	28
SEP	17.64	.77	4	32
OCT	31.38	.57	13.39	41.39
NOV	55.08	.33	36.98	64.98
DEC	71.91	.23	55.18	83.18

ESTIMATED ANNUAL SPACE HEATING 30.37 GJ, OR 8437.4 KWHRS.
ANNUAL SOLAR FRACTION = .41
TOTAL ANNUAL ENERGY CONSUMPTION = 18657.4 KWHRS
S.E.E.H. PROGRAM REQUIREMENTS FOR TOTAL ENERGY CONSUMPTION = 21409.79 KWHRS

*** ANNUAL PREDICTED FUEL COSTS ***

FUEL COSTS ARE FOR TORONTO AS OF SEPT16

ENERGY SOURCE	COST PER UNIT	SPACE HEATING	HOT WATER	LIGHTS AND APPLIANCES
ELECTRICITY	3.8C/KWH	$ 320.62/YR EFF.= 100%	$ 194.18/YR EFF.= 100%	$ 194.18/YR EFF.= 100%
NATURAL GAS	21C/M3	$ 244.56/YR EFF.= 70%	$ 188.51/YR EFF.= 55%	--
OIL	38C/LITRE	$ 422.81/YR EFF.= 70%	$ 325.9/YR EFF.= 55%	--
PROPANE	38C/LITRE	$ 644.12/YR EFF.= 70%	$ 496.48/YR EFF.= 55%	--
WOOD	55/M3	$ 652.09/YR EFF.= 50%	$ 493.65/YR EFF.= 40%	

Appendix II: The Sheridan Subdivision.

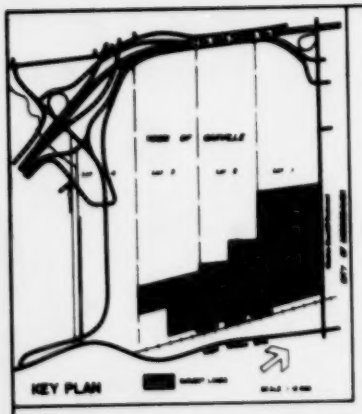
Developer: Sheridan Nurseries Ltd.

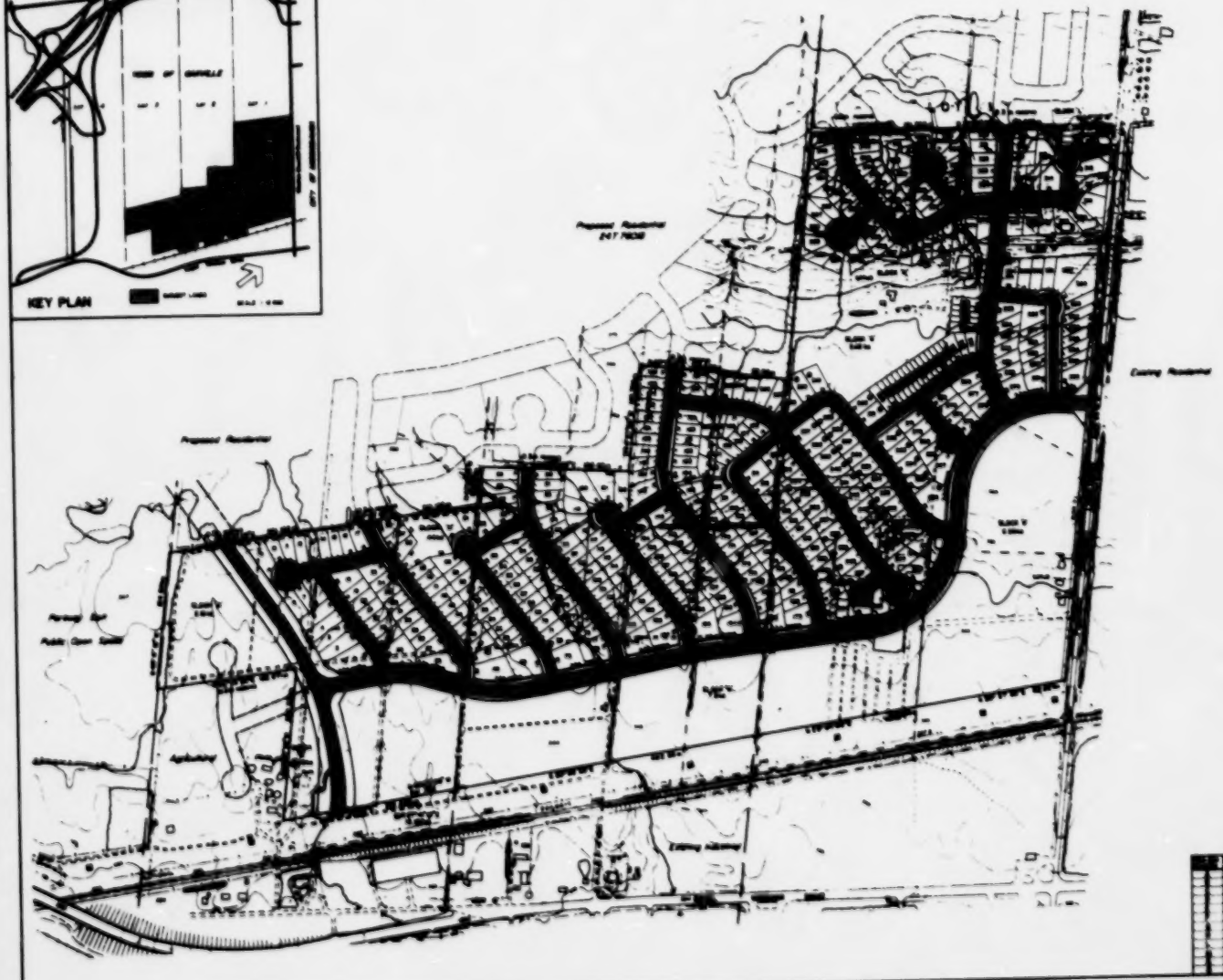
Agent: Dunlop, Farrow, Aitken Ltd.

1. Agent engaged Enerplan Consultants Ltd. to prepare a solar sensitive plan of subdivision. Thus the original developer intent was to prepare and submit a solar plan of subdivision to the Town of Oakville for approval.

2. The solar subdivision plan, which achieved in excess of 80% solar orientation of lots satisfied the standard requirements of the approving authorities without encountering unusual time delays.

3 The plan, as shown overleaf, was Draft Approved by the Town of Oakville and Region of Halton in July, 1982.





Part of Lots 1, 2 and 3
Concession 2 S.D.S.
TOWN OF OAKVILLE
Regional Municipality
of HALTON

Additional Information under section 33(2) of the planning act.

information required by clauses a,b,c,d,e,f,g,j, shown on draft and key plans
h,municipal water available.
i, sandy clay loam.
k,sanitary and storm sewers and paved roads.
l, as shown.

Owner's Certificate

We the owners by valid purchase/sale agreement authorize DUNLOP FARROW AITKEN ENERPLAN CONSULTANTS LTD. and McCONNELL MAUGHAN to prepare and submit this plan to the Region of Halton.

dated

Surveyor's Certificate

I certify that the boundaries of the land to be subdivided are correctly shown.

dated

Designer's Certificate

ENERPLAN Consultants Ltd

McConnel Maughan

General Notes

Land Use	Zoning	Lots/Ha	Units	Population

POOR

QUALITY

ORIGINAL